First look at trigger primitives with ProtoDUNE data

Philip Rodrigues

University of Oxford

October 15, 2018

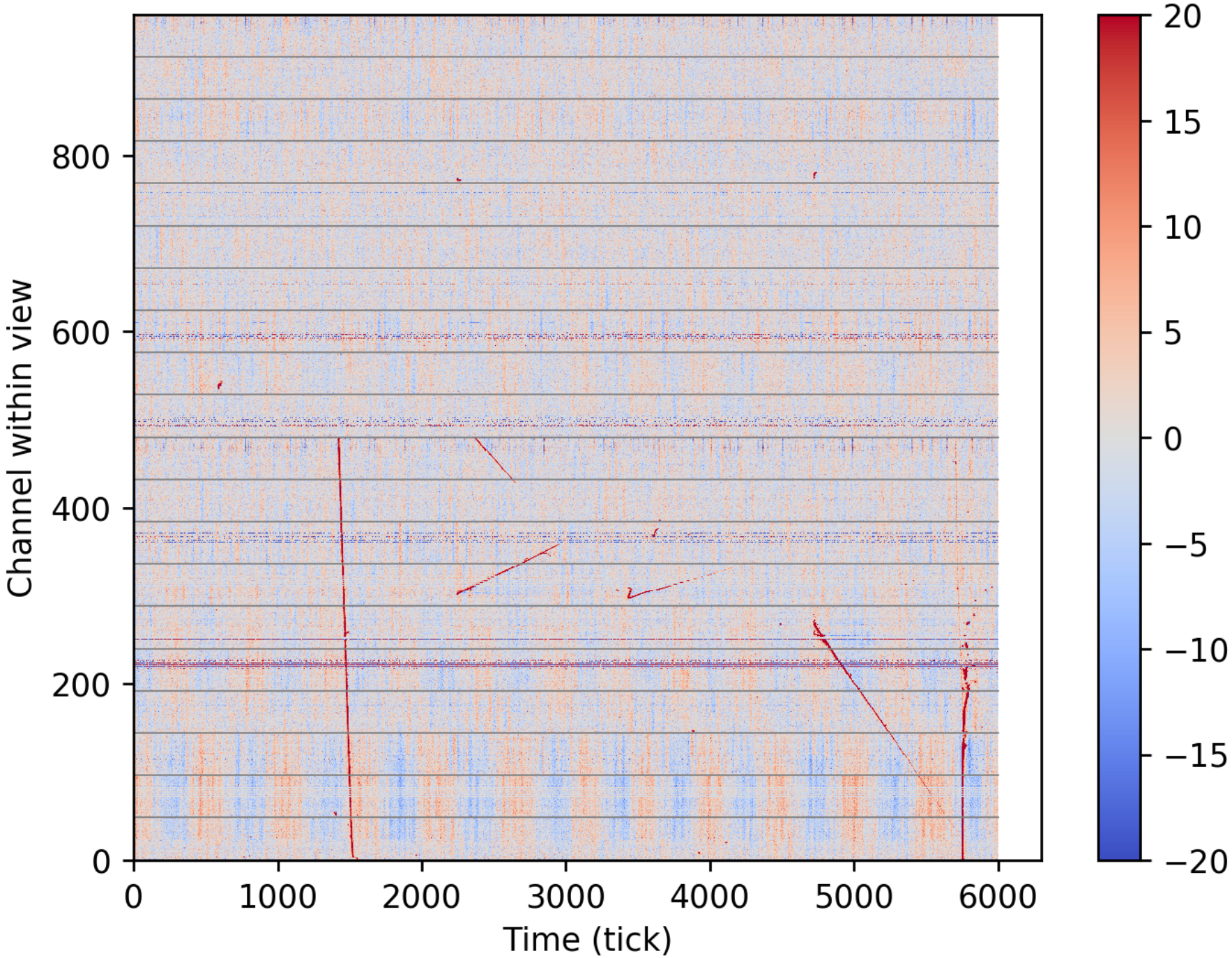
Introduction

- Two threads:
  1. Look at ProtoDUNE waveforms to understand what the noise is like
  2. Run trigger primitive finding code on ProtoDUNE data
- David Adams has done a more structured look at noise, eg:

  https://indico.fnal.gov/event/18638/contribution/2, https://indico.fnal.gov/event/18427/contribution/2

Waveforms

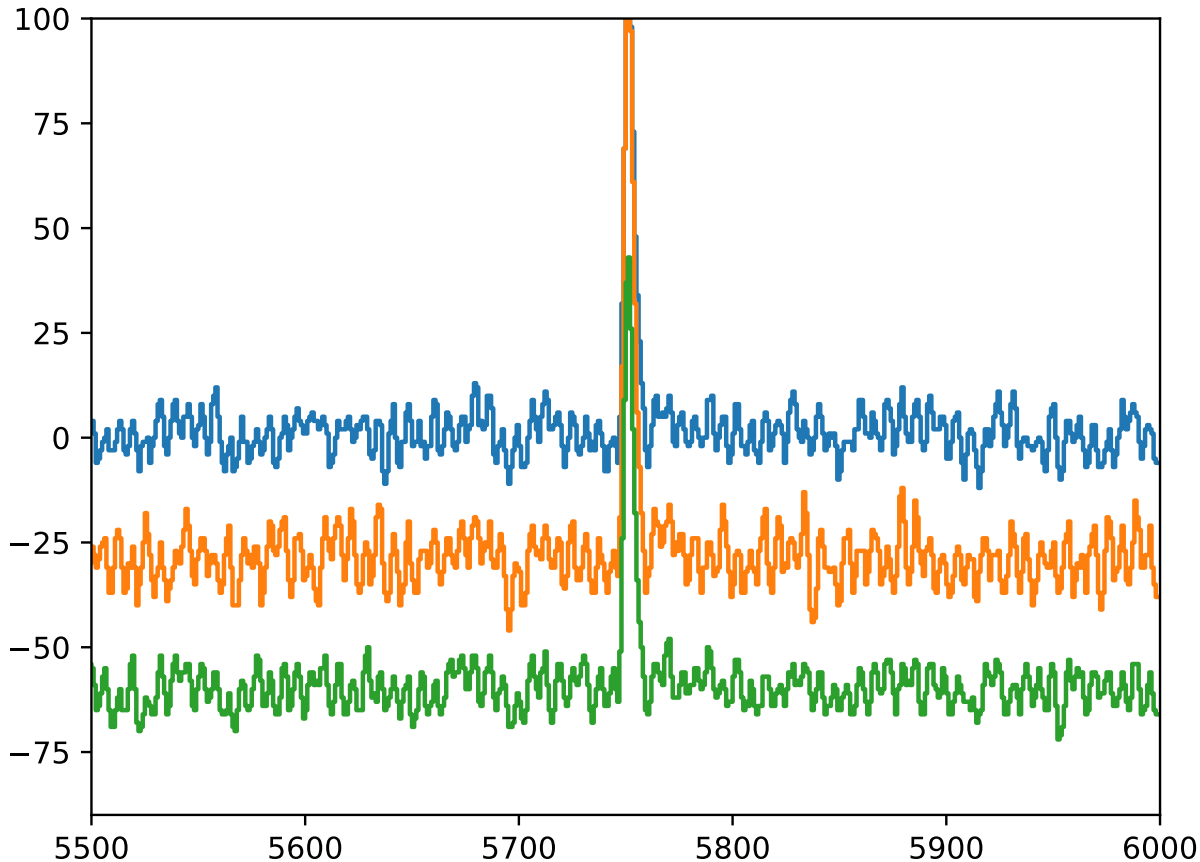
- Next slide shows collection waveforms from one APA, one event. (Run 4643 Event 41, APA 5 (offline 1))
- I subtracted the median of each channel as the pedestal
- Grey horizontal lines are the boundaries of front-end motherboards
- The colour scale is -20 to $+20$ ADC to look at noise rather than signal
- I'm showing both collection planes: cryostat-facing and wall-facing


Channel within view
0
200
400
600
800
0
1000
2000
3000
4000
5000
6000
Time (tick)
20
15
10
5
0
−5
−10
−15
−20

Commentary

- There's a clear coherent component to the noise with a fixed frequency of few 10s of kHz. Seems to be modulated at a few kHz
- Variations in noise across the APA. Some appears spatial, some appears board-related
- Some obvious bad channels
- Some signals on the wall-facing plane (radiologicals?)

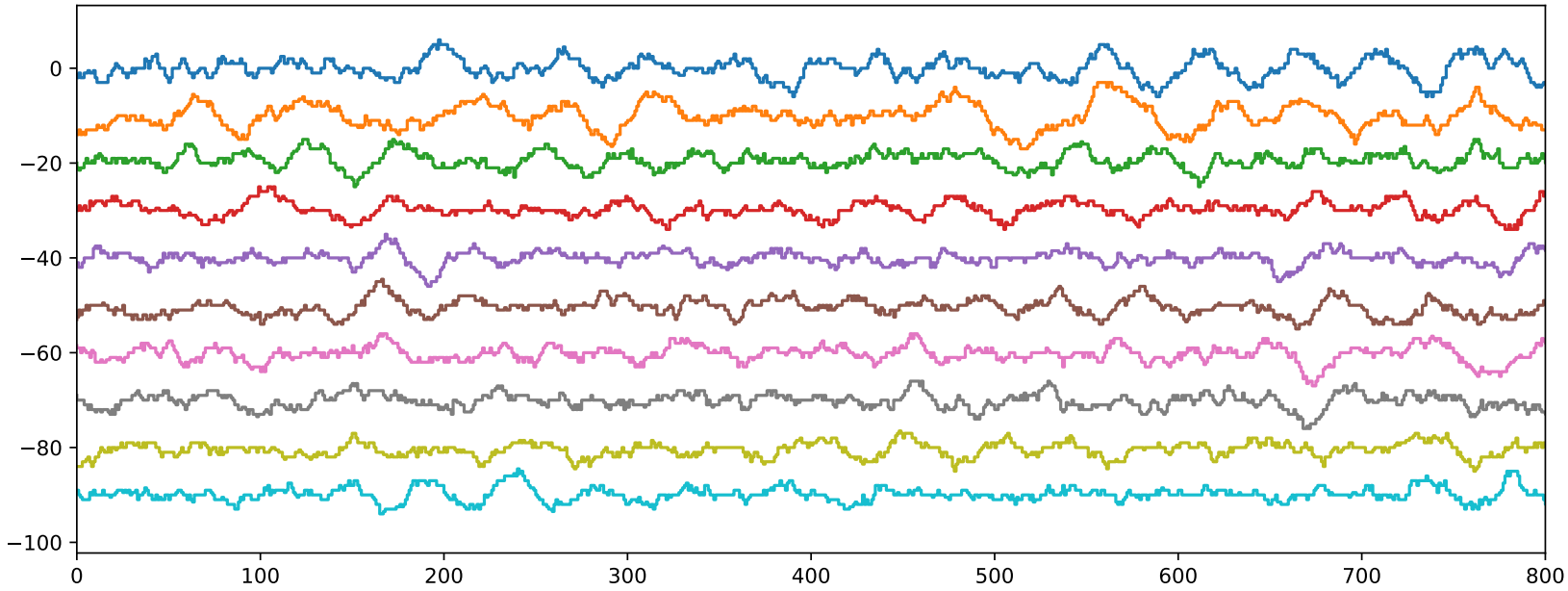
Waveforms with signal



Channels 40–42 as numbered in the APA 2D plot

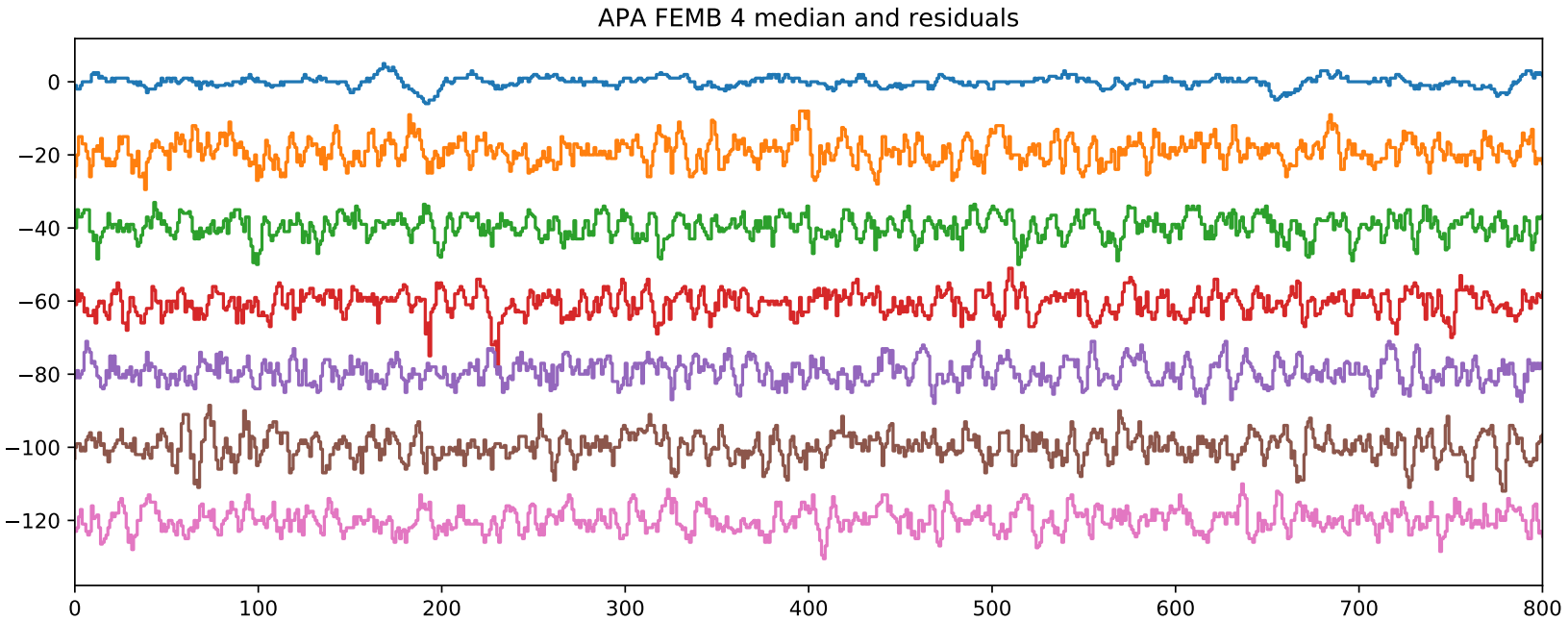
- This is from the noisier region of the detector
- Signal still clear over the noise

An attempt to extract the coherent noise component 1



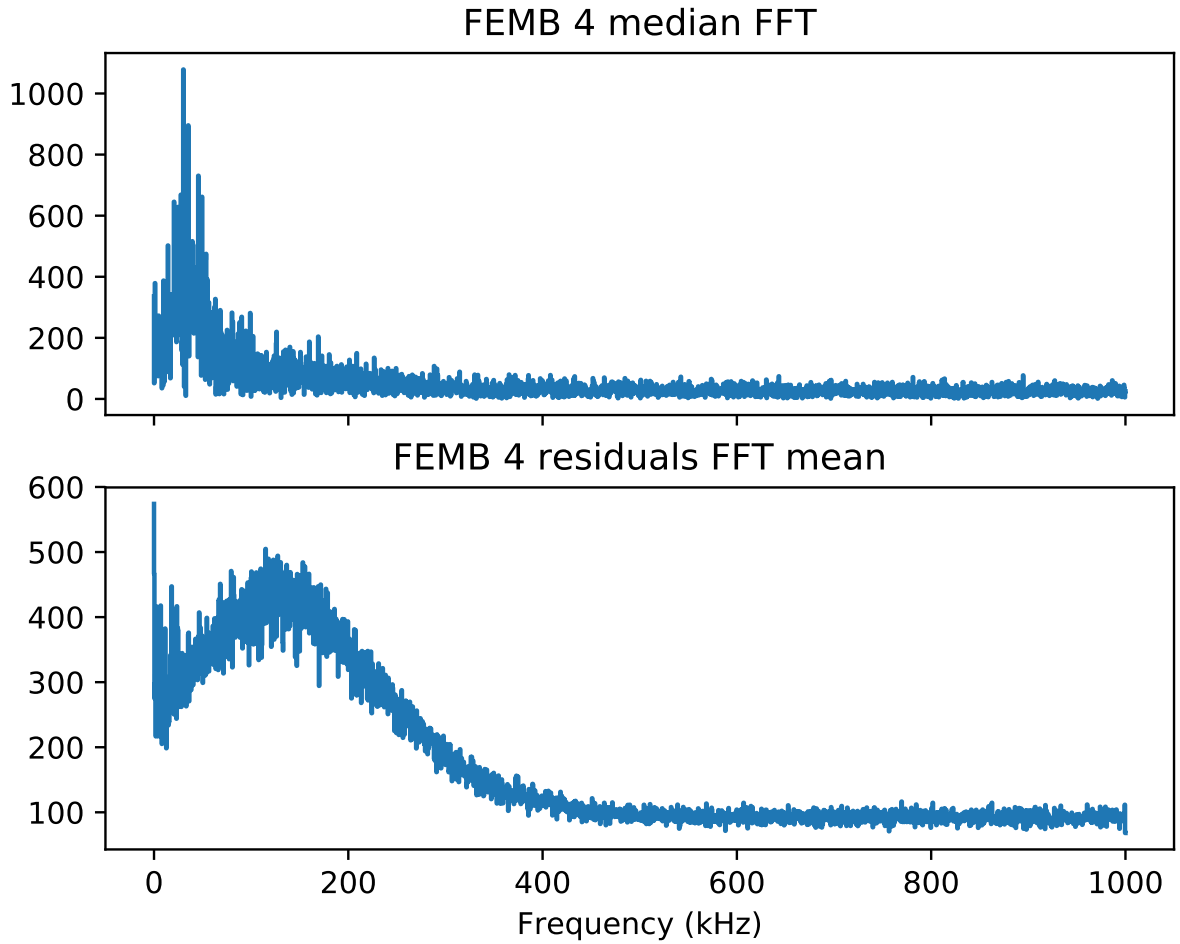
- Take wall-facing collection wires (to minimize signal). Subtract median from each channel
- Within each FEMB, at each tick, find the median of the 48 channels. This is plotted above, for each wall-facing FEMB in one APA

An attempt to extract the coherent noise component 2



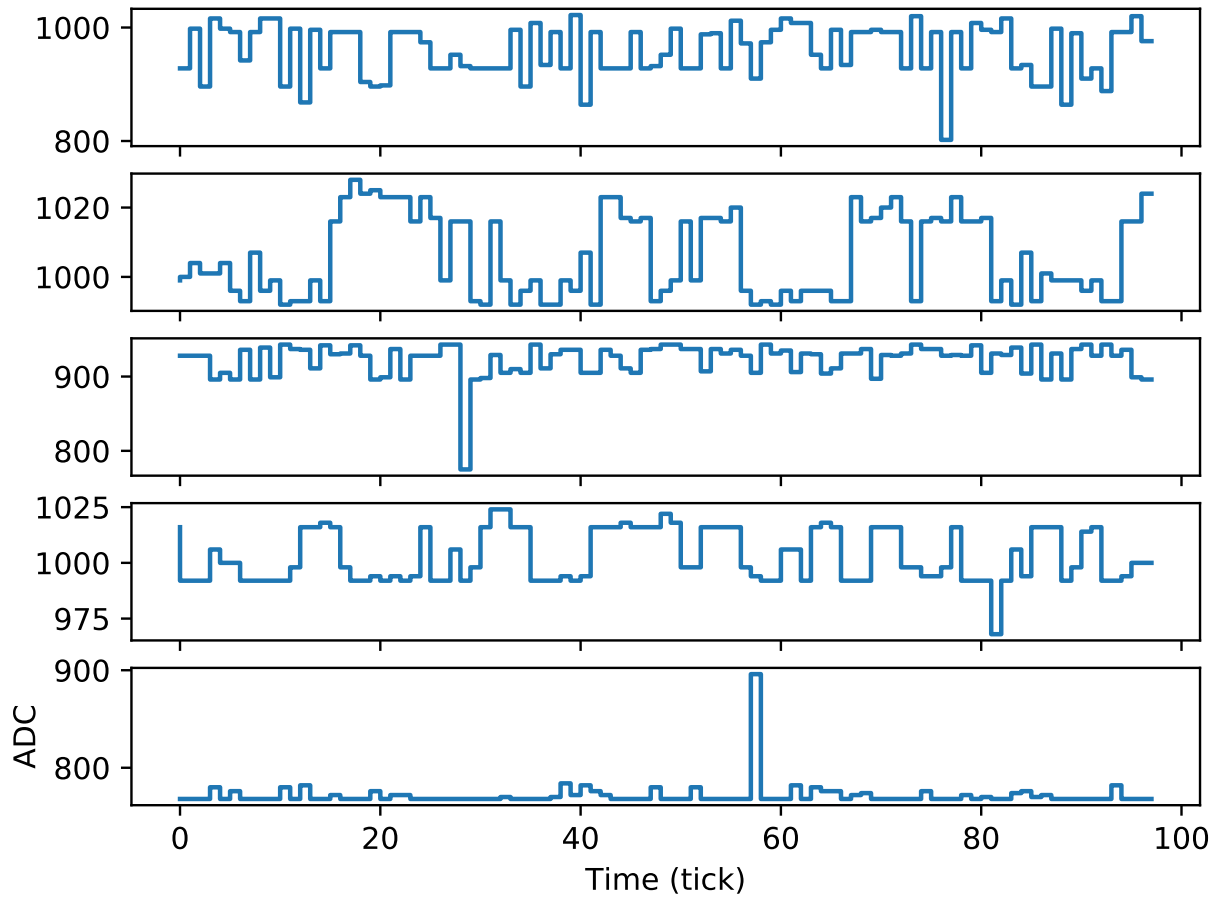
- For one of those FEMBs, here's the median (top line) and the residuals from a subset of the channels
- Clearly higher-frequency components to the residuals
- The incoherent component is larger than the coherent component

An attempt to extract the coherent noise component 3



- Here's the FFT of the median (top) and the mean of the FFTs of the residuals (bottom)
- No obvious spikes. I think this suggests it will be tricky to simulate the coherent component accurately with a smooth FFT plus random phases
- Maybe the easiest approach to simulating "ProtoDUNE-like" noise is to make a "library" of these median waveforms, add those manually, and use inverse-FFT for the incoherent component

Bad channels



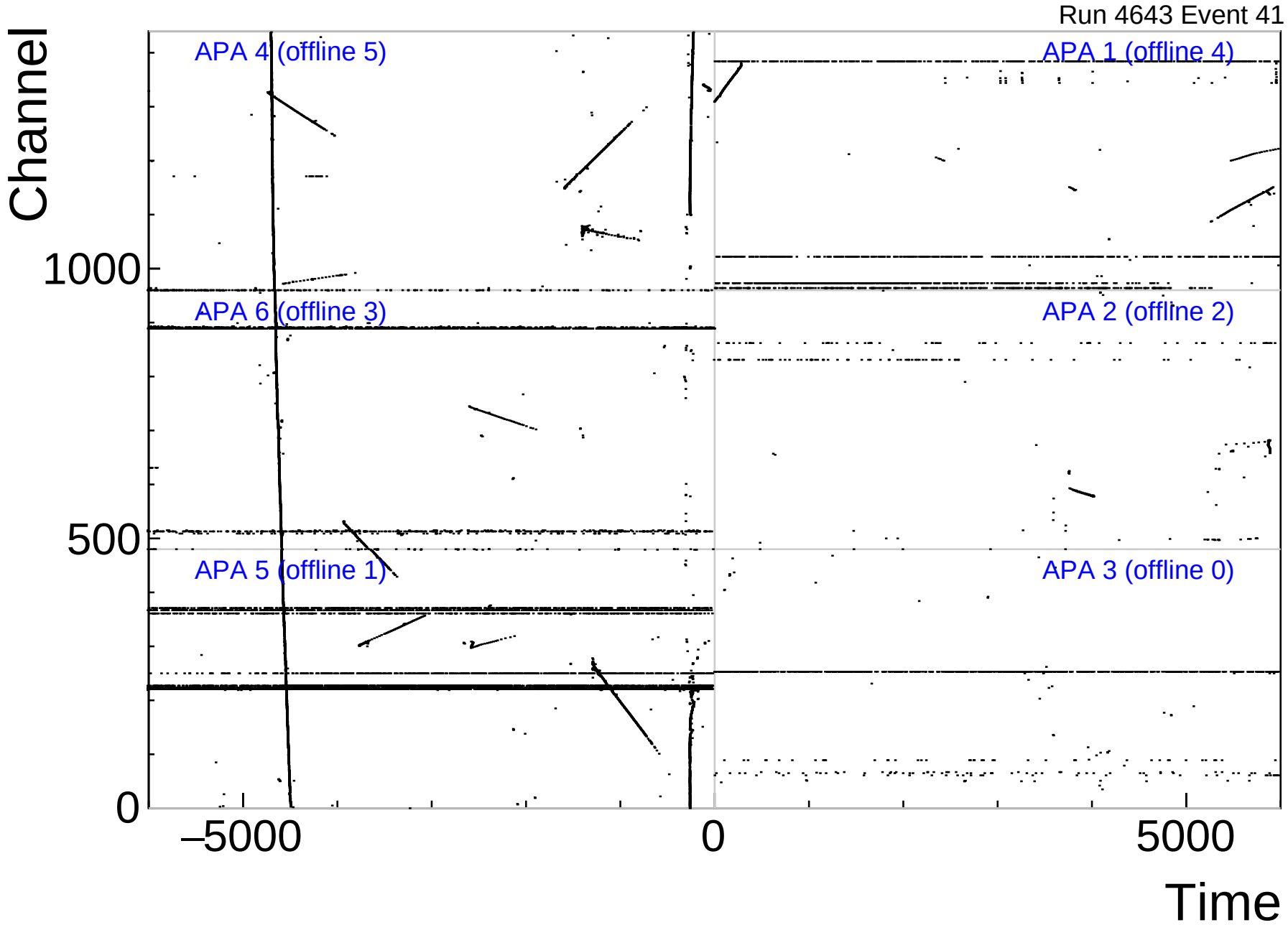
- Waveforms from a few bad channels
- They're "stuck bits"-like, rather than just higher RMS noise

Trigger primitives

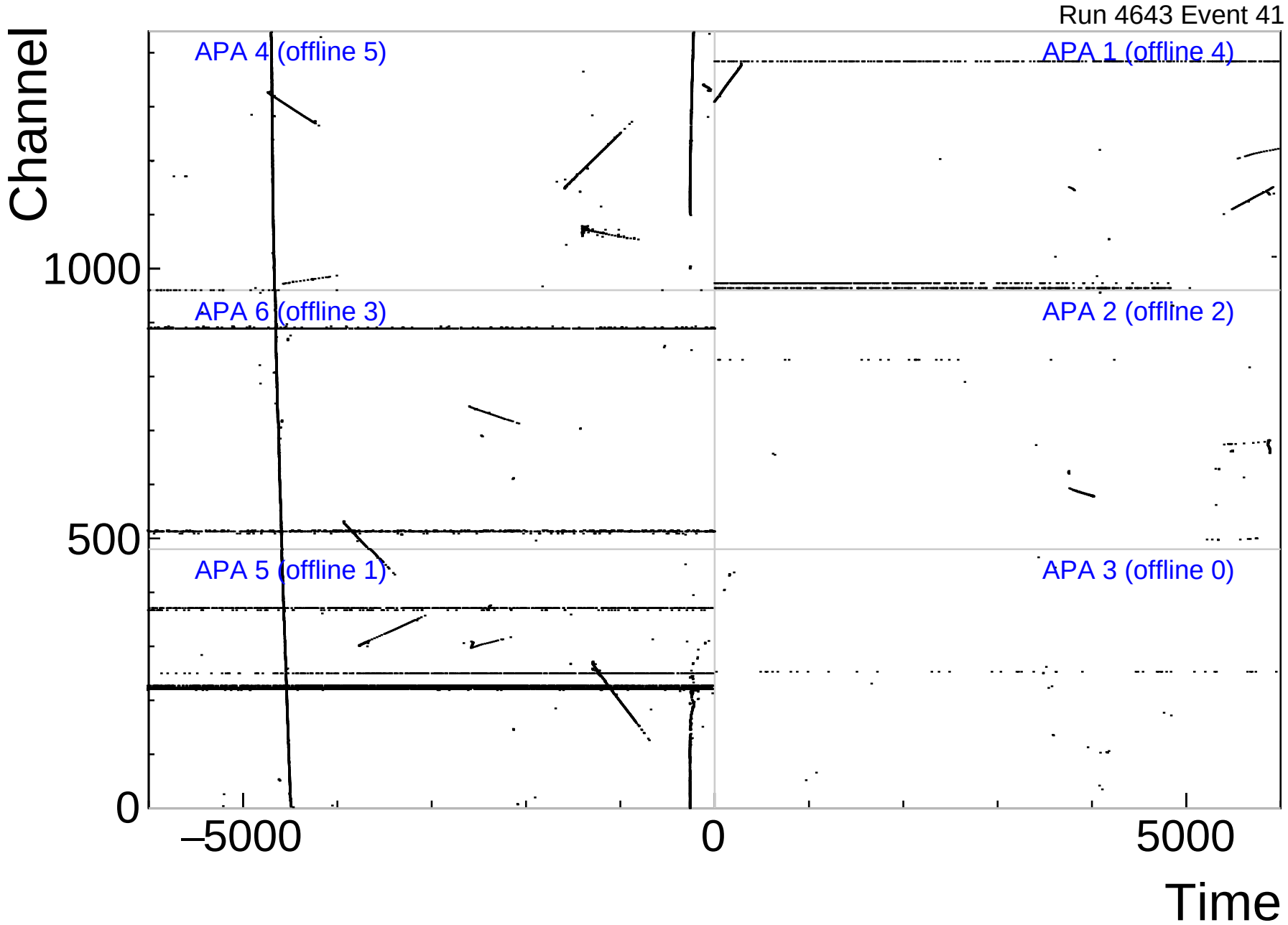
Introduction

- I ran my trigger primitive-finding code on the same data, starting with raw waveforms, pedestal subtracted and 7-tap filtered
- Difficult to think what to do that's quantitative, but qualitative is easy
- Event displays and trigger primitive rates follow...

Trigger primitives found with threshold 20 ADC



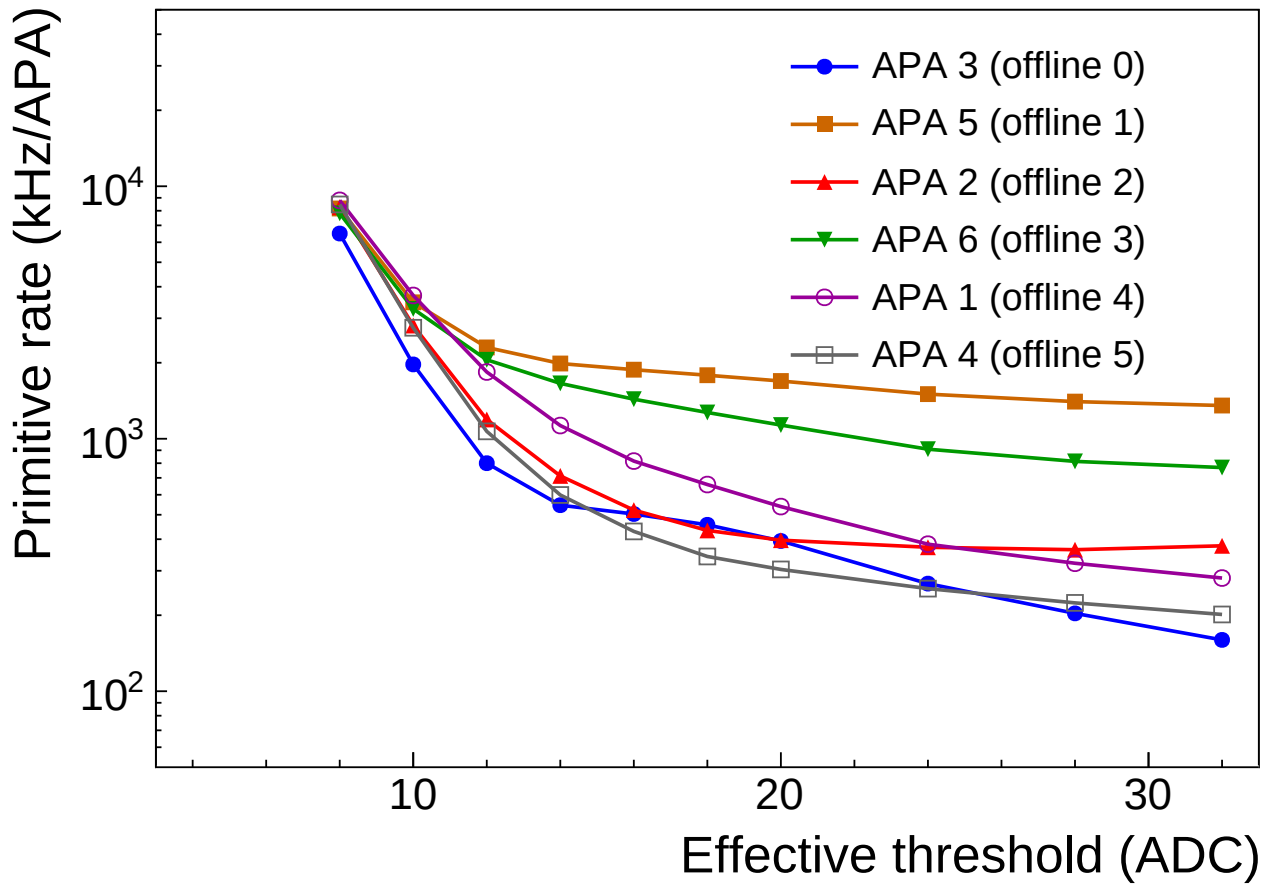
Trigger primitives found with threshold 32 ADC



Conclusions from event displays

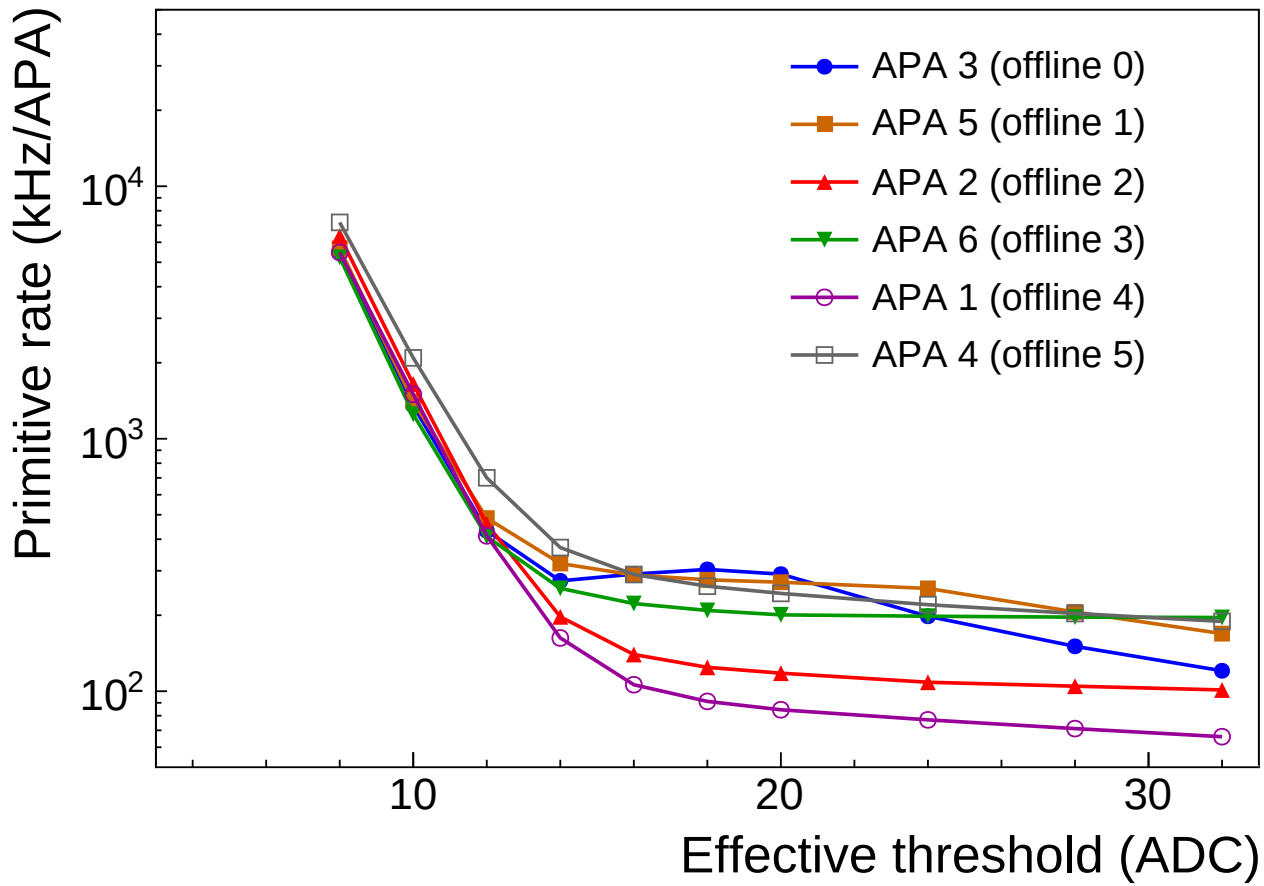
- Trigger primitives look sensible
- The bad channels show up as high TP rates
  - I tried identifying the bad channels by looking for high rates, but it works imperfectly, as described in the backup slides
- There's not such a big difference between 20 and 32 ADC thresholds

Trigger primitive rate as a function of threshold



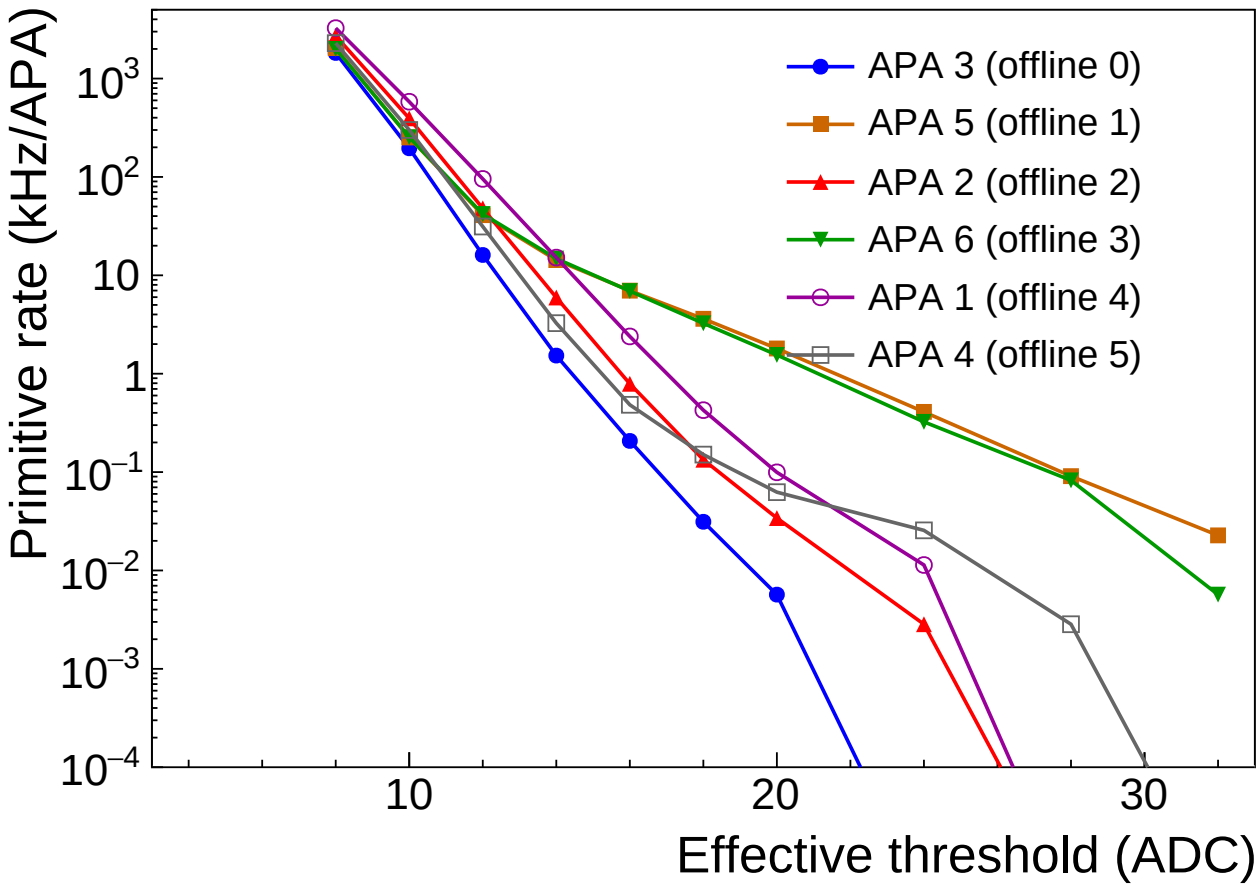
- The trigger primitive rate as a function of threshold for each APA
- This run has HV on, so the floor is where we hit the cosmics signal, I think
- All (collection) channels are included here, whether high-TP-rate or not

Trigger primitive rate *vs* threshold, "bad" channels excluded



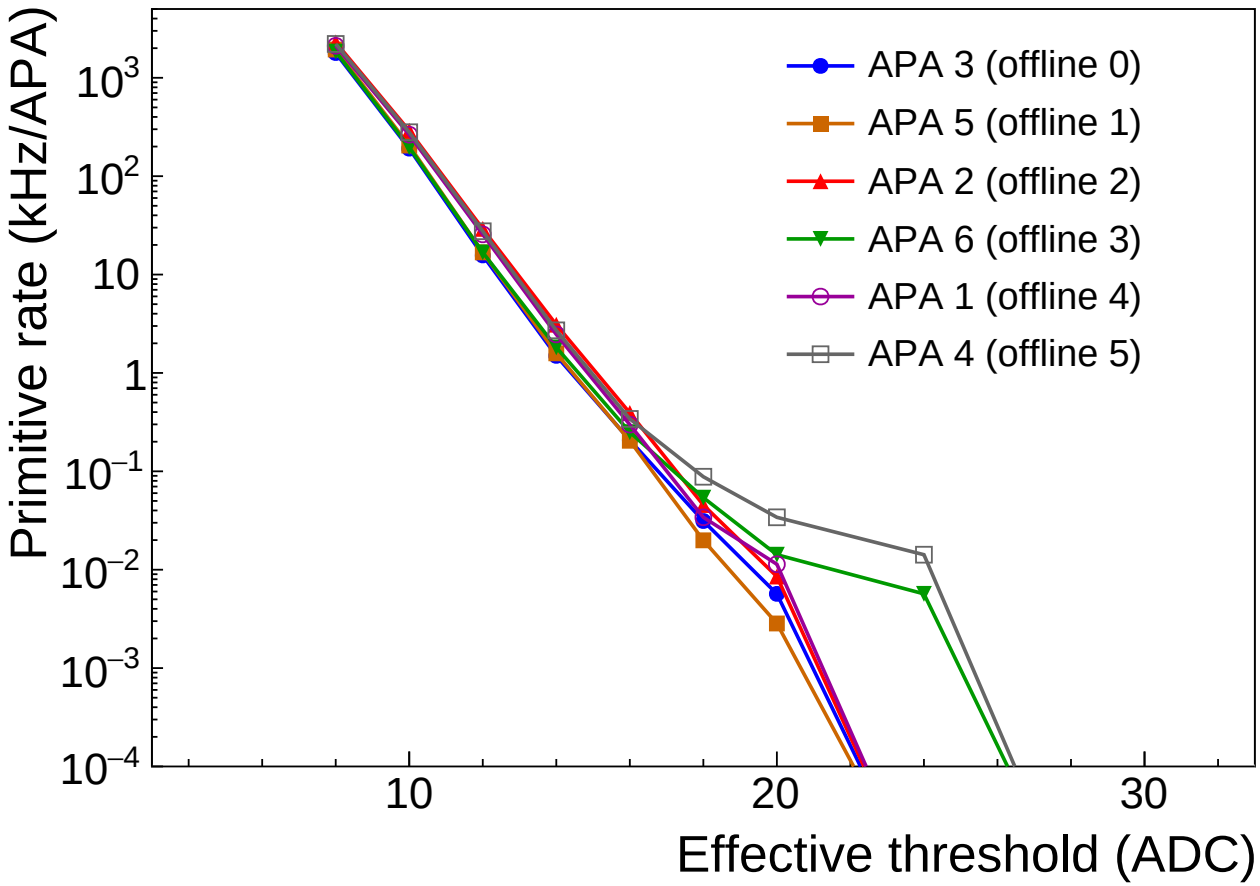
- The same, with identified bad channels removed
- The APAs get more similar to one another, which is good (but sort of by definition)

Trigger primitive rate *vs* threshold: HV off



- Now here's the same for run 3817, before the HV was turned on, so this is noise-only

Trigger primitive rate *vs* threshold: HV off, noisy channels excluded



- The same, with identified noisy channels removed. (I reran the noisy-channel algorithm on this run, so the threshold and set of noisy channels is different to the one for 4643)
- The APAs get more similar to one another, which is good, but I don't understand the difference in rate at high threshold

Conclusions

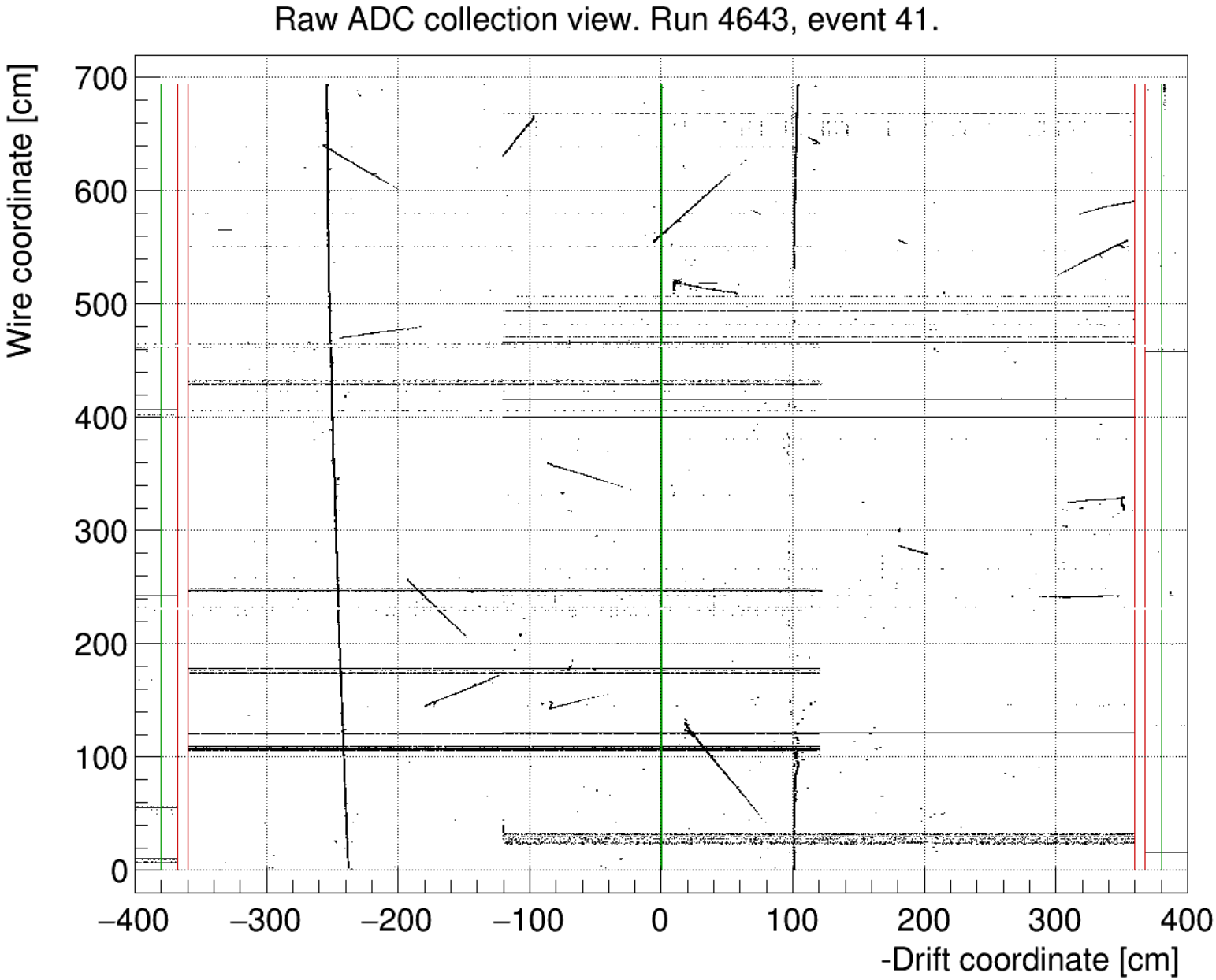
- The trigger primitive finding code runs nicely on ProtoDUNE data; looks qualitatively OK
- One quantitative thing we could do is compare my trigger primitives to hits formed by the offline reco
- Any other quantitative ideas?
- The noise has a noticeable coherent component that I'm not sure of the best way to model

Backup slides

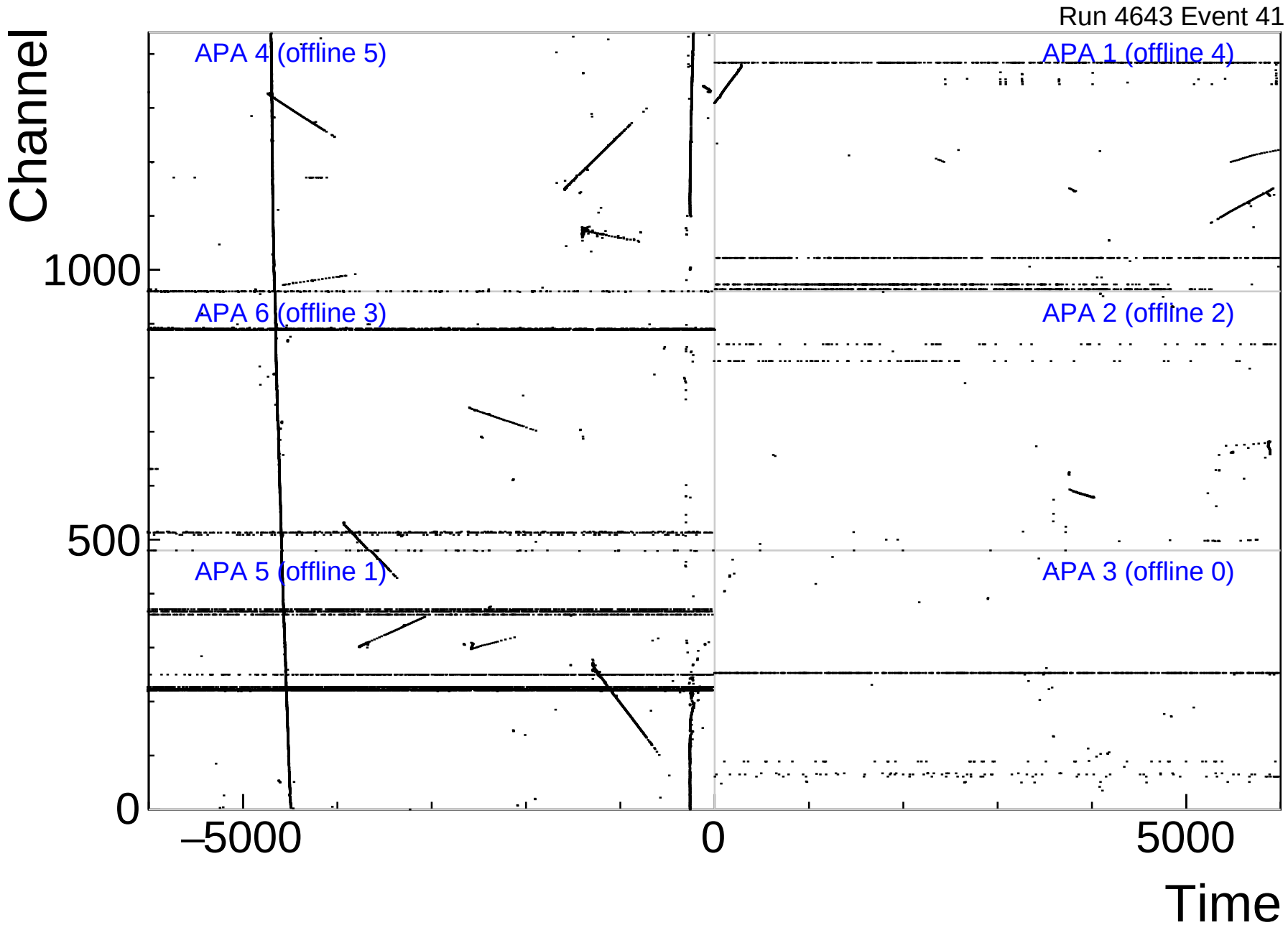
"Event display"

- I roughly copied the style of David Adam's monitoring plots, as seen on next page, and described at https://indico.fnal.gov/event/16526/session/34/contribution/83
- He plots anything over 20 ADC from pedestal, converts time to drift co-ordinate with an estimate of drift speed
- I plot trigger primitives found by my method on collection channels. x axis is time, flipped for beam-left APAs to look like an event display
- Only the cryostat-facing collection planes are shown

David Adams's event display (samples above 20 ADC)



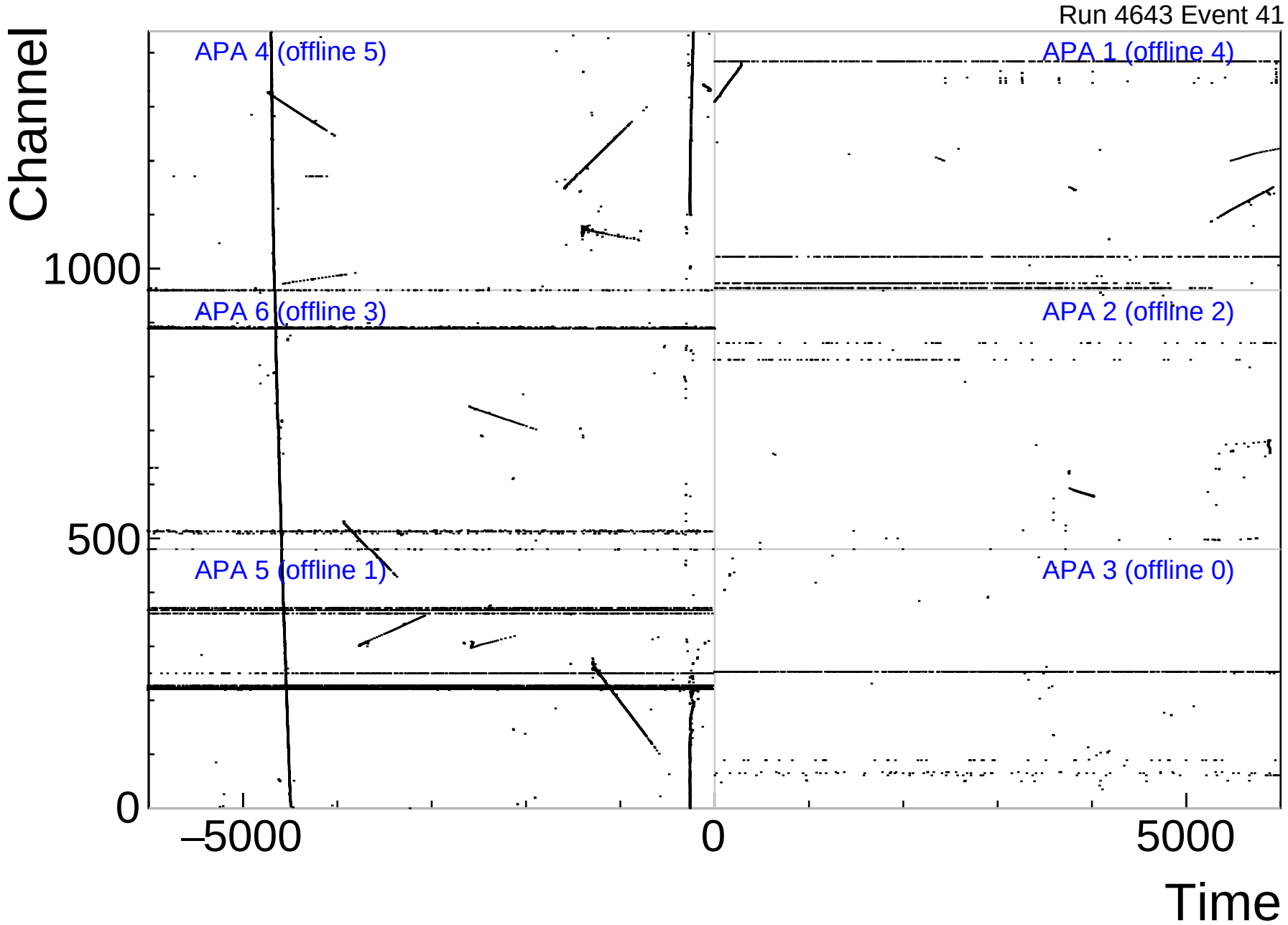
My event display (trigger primitives found with threshold 20 ADC)



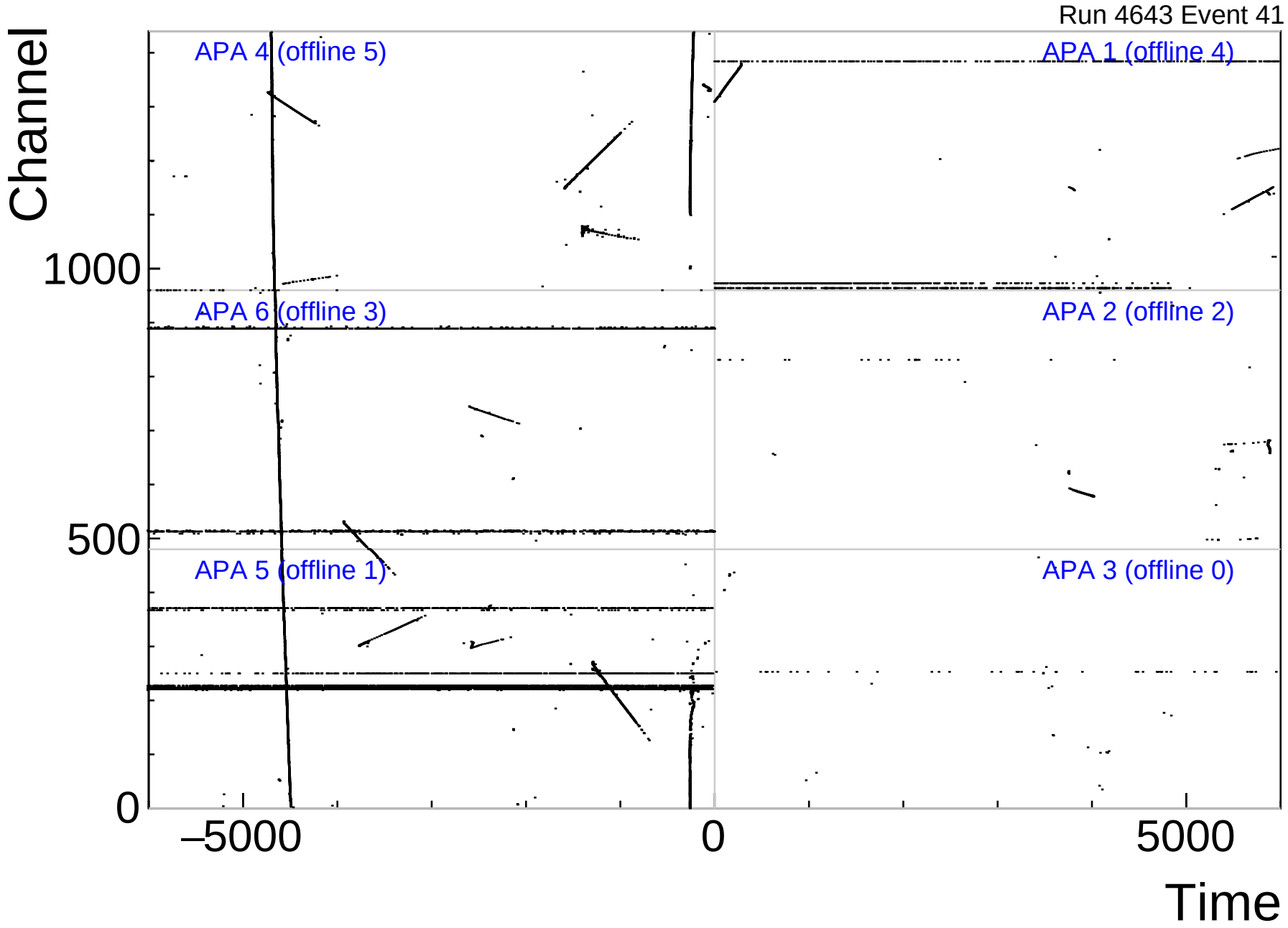
Comments

- I managed to reproduce David's event display: useful sanity check
- The trigger primitives look like real hits. That's good
- There are clearly some noisy channels
- Offline and "online" APA numbering schemes are different. I'm using the scheme used "online" (where, eg, APA 6 is the one read out by FELIX)

My event display (trigger primitives found with threshold 20 ADC)



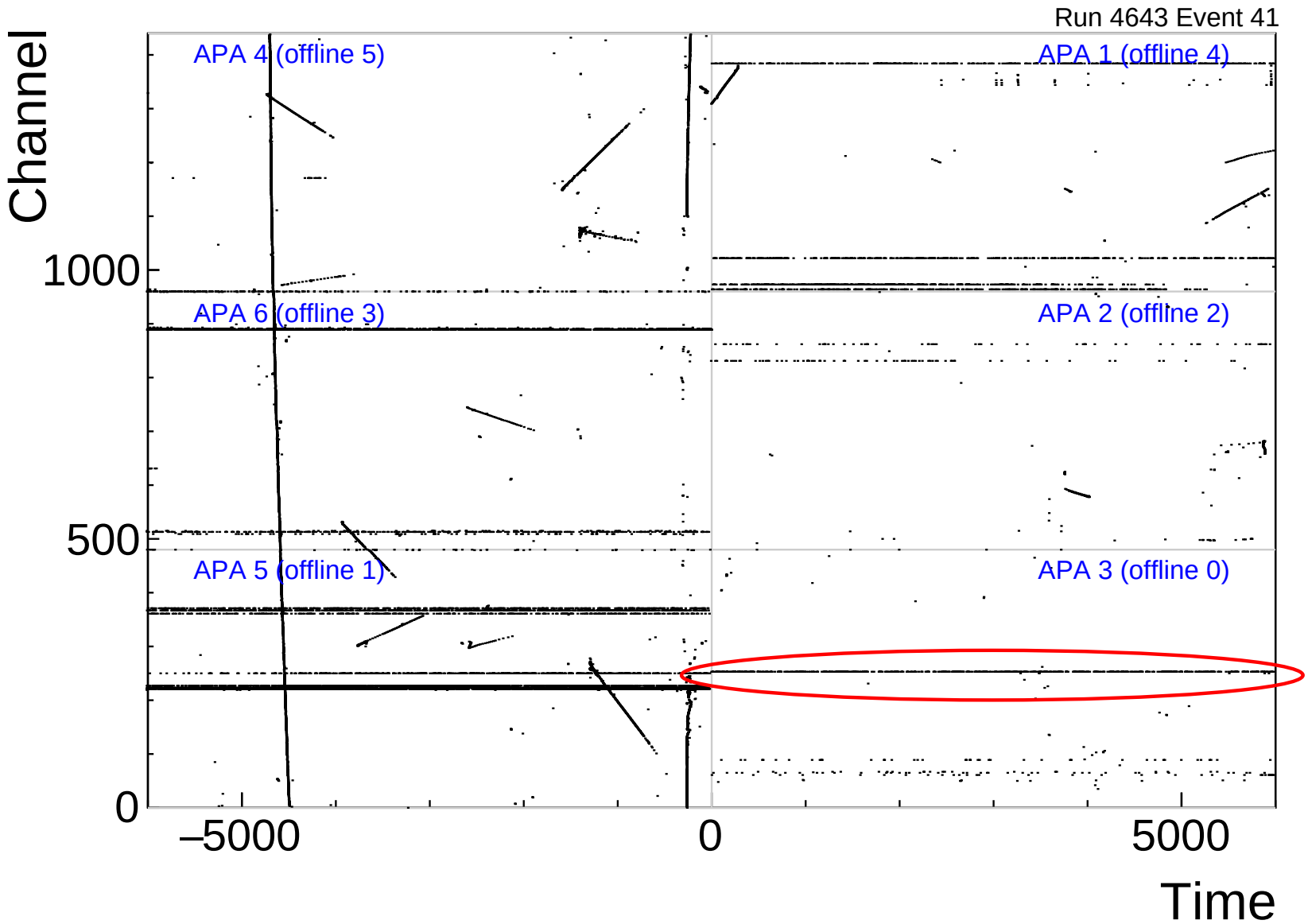
My event display (trigger primitives found with threshold 32 ADC)



Vetoing noisy channels

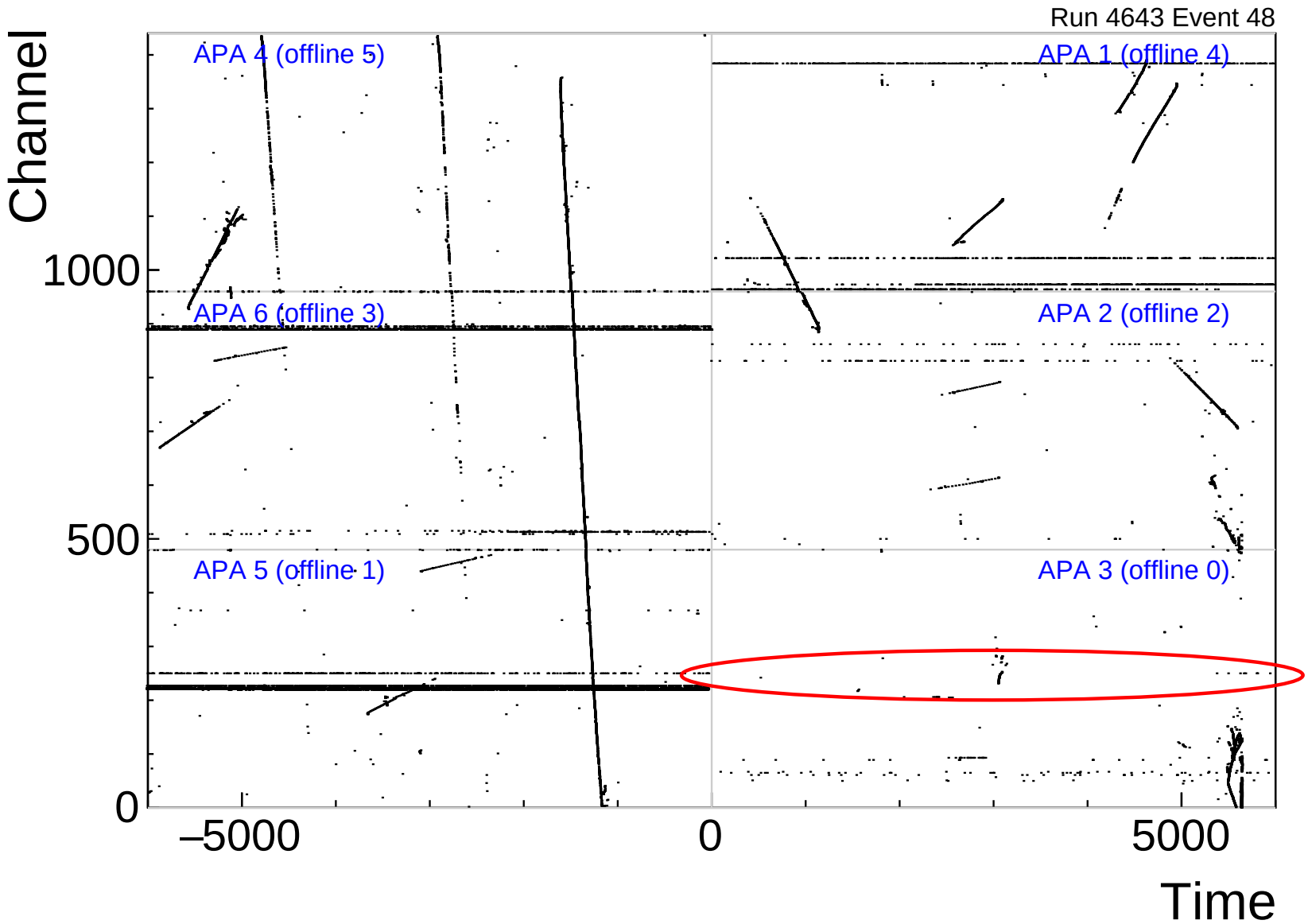
- I tried to identify "bad" channels as those with high trigger primitive rates across a set of events
- This sort of works, but sticky codes appear to sometimes be transient, eg a few events

A transient noisy channel: event 41



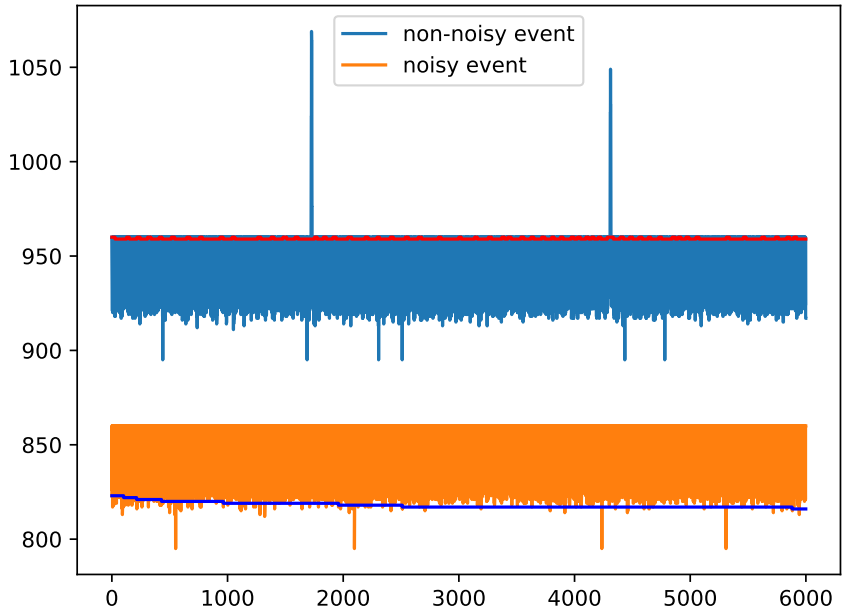
- Channel in APA 3 is noisy...

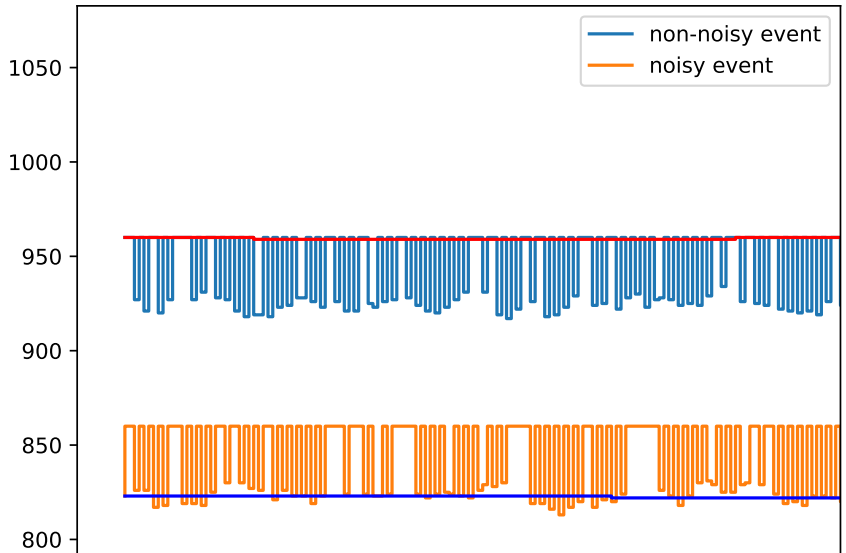
A transient noisy channel: event 48



- . . . but a few events later it's quiet again

Waveforms

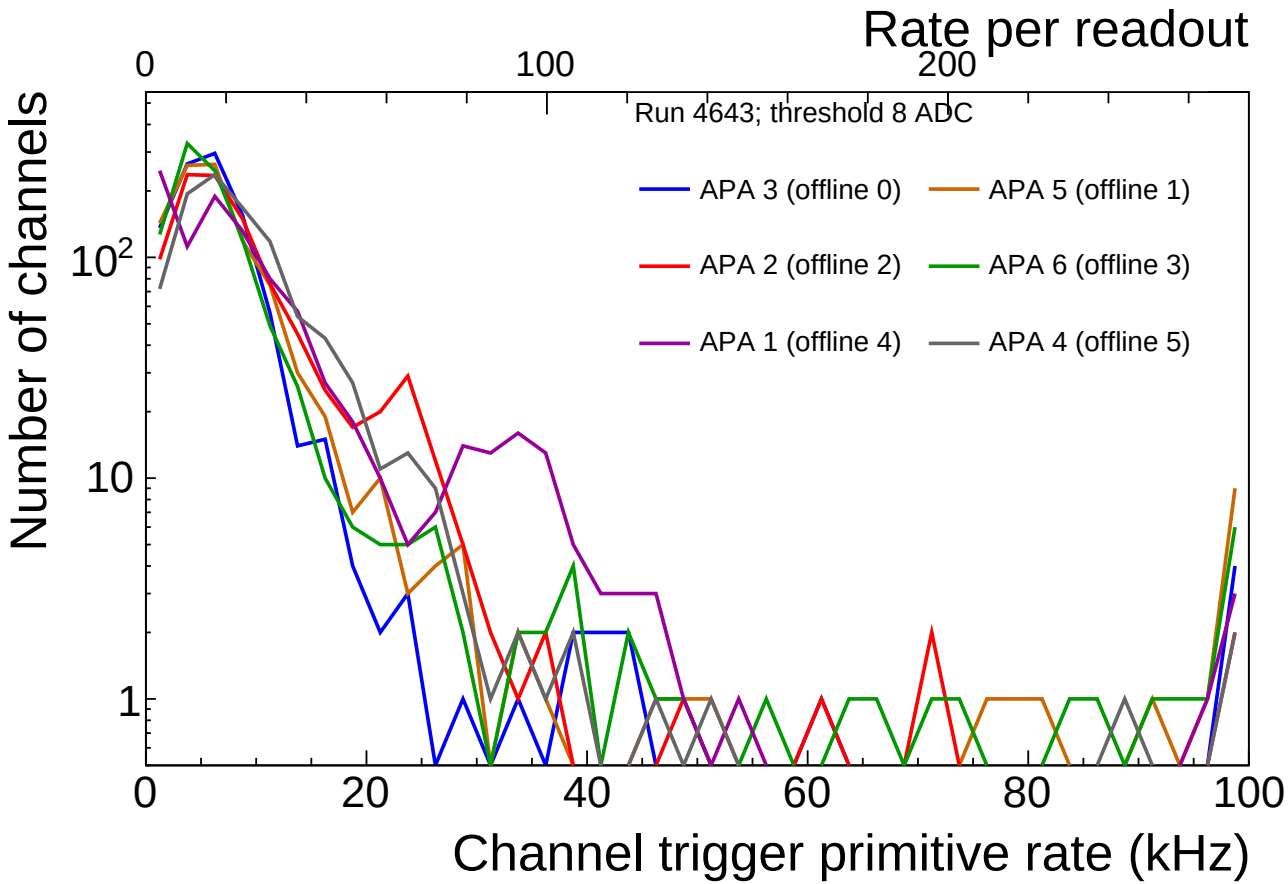

non-noisy event
noisy event
1050
1000
950
900
850
800
0
1000
2000
3000
4000
5000
6000


non-noisy event
noisy event
1050
1000
950
900
850
800

Conclusions so far

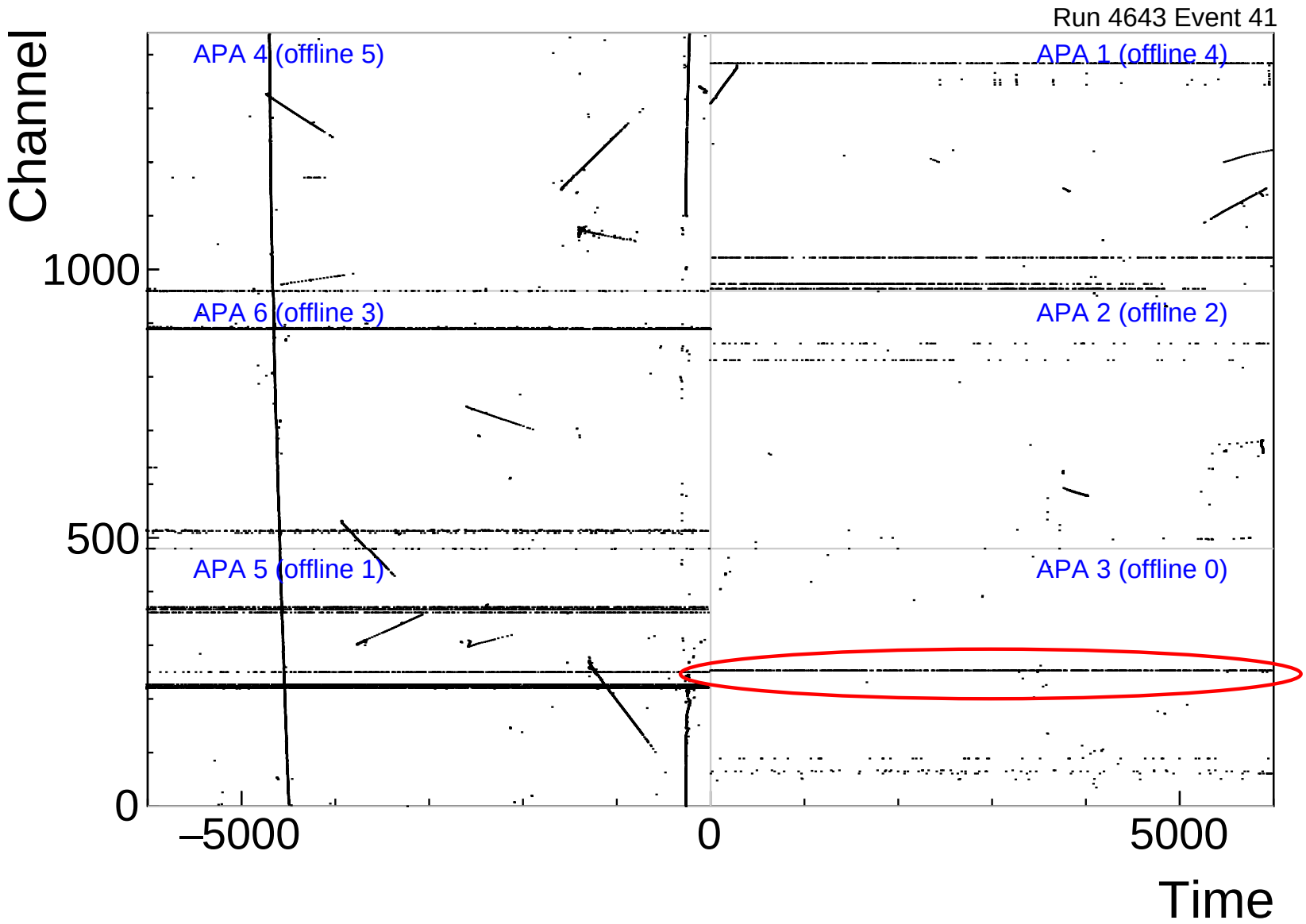
- I think this is enough to suggest that making serious use of this data for our purposes requires a proper look at data quality and a concerted effort to identify and mitigate bad channels
- That effort is going on:
  - https://indico.fnal.gov/event/18427/contribution/2
  - https://indico.fnal.gov/event/16526/session/34/contribution/83
  - https://indico.fnal.gov/event/18450/contribution/5
- But I did something quick and dirty anyway...

Channel primitive rates



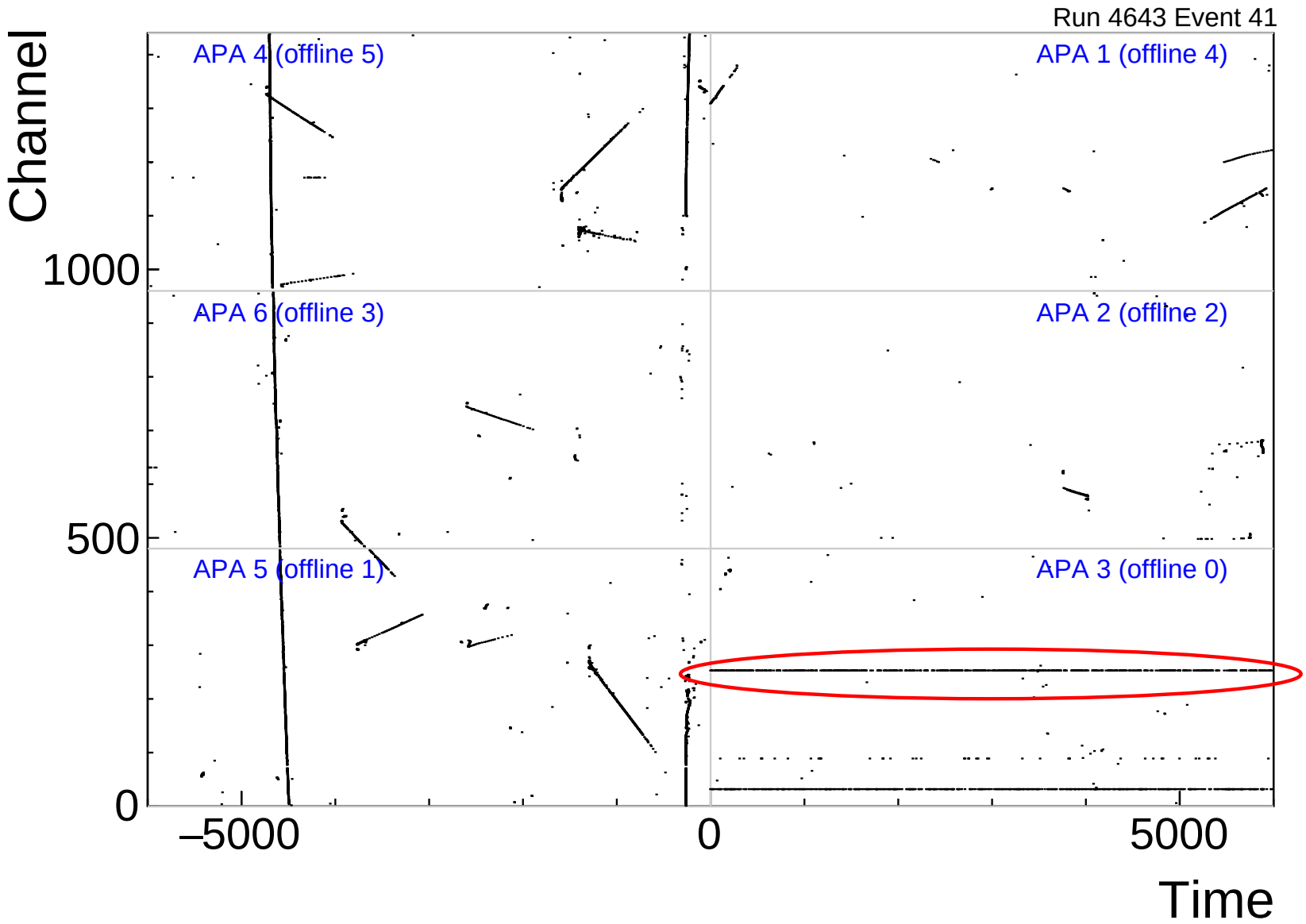
- Here's the distribution of trigger primitive rates per channel, for a low trigger primitive threshold of 8 ADC counts. This is calculated by summing over all the events in the input file I used
- This suggests a "noisy channel" threshold of around 60 hits per event (top scale)
- There's an errant factor of two here somewhere because I mapped the wall-facing channels onto the cryostat-facing channels, but I've done that consistently throughout, so I think the only thing that's wrong is the labelling on the x axis

Event 41 again



- This slide for comparison with the next slide, which has noisy channels removed

Event 41 again, with noisy channels removed



- Many bad channels removed, but the transient noisy channel is not, because in defining the rate, I averaged over all events